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HUNTSVILLE, ALABAMA
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Memorandum

TO See Distribution

DATE April 5, 1962
Memo #M-ASTR-TSJ-5-62

FROM SATURN Office, Astrionics Division
M-ASTR-TSJ

TMX 51831

SUBJECT Technical Information Summary Concerning SATURN Vehicle SA-2

This memorandum outlines, through a series of sketches, some of the important features and sequences concerning the second SATURN vehicle. The sketches are devoted primarily to the control and instrumentation aspects of the vehicle but also touch on the launch facility and countdown schedule.

1. Introduction

The SATURN C-1 Program has as its primary objective, the development of a large two stage vehicle for use in space operations. Ten vehicles are planned for the research and development phase and are divided into Block I (SA-1 through SA-4) and Block II (SA-5 through SA-10). The first four SATURN vehicles will be launched from complex VLF 34 at Cape Canaveral, on an azimuth of 100 degrees East of North. The general arrangement of launch complex VLF 34 is seen in Figure 1.

In the Block I series, only the S-I stage is propelled and there is no separation of the S-I stage from the dummy upper stages. The S-IV stage will be active on the Block II vehicles (SA-5 and subsequent).

The first vehicle of this series (SA-1) was launched with no technical holds at 1006 EST on October 27, 1961 from Launch Complex 34, AMR, on an azimuth of 100° East of North. The flight performance of the vehicle was excellent; no malfunctions or deviations were observed which could be considered a serious system failure or design deficiency. However, sloshing instability was encountered after 90 seconds of flight; although there was more sloshing than expected, it did not approach the point of endangering vehicle control or structural integrity. The maximum engine deflections due to the effects of sloshing were ±1/2 degree in pitch and yaw, and ±1/4 degree in roll. Additional anti-slosh baffles have been placed into the lower end of the eight outer tanks (See Figure 8) on SA-2 to considerably reduce propellant sloshing during the period around 80 to 105 seconds.

RAT 3307

Pitch actuator deflections of 2 degrees resulted from the tilt program commands, as expected. Even though this did not have any appreciable effect on the stability of the vehicle, a "smooth" tilt program is being introduced on SA-2 and subsequent vehicles. (See Figure 7).

2. Control System (See Figure 5)

Control information is supplied to the Flight Control Computer by the following control sensors:

a. The ST-90 Stabilized Platform System which provides the attitude reference signals, and

b. The Local Angle-of-Attack Transducers which provide the angle-of-attack signals.

The necessary attitude rate information is obtained by electrical differentiation of the three attitude signals in the Flight Control Computer by means of R-C networks.

This computer filters, amplifies and/or attenuates, shapes, and sums these signals and in turn issues steering commands to the eight hydraulic actuators for proper positioning of the four outer H-1 engines, which effect vehicle control in pitch, yaw and roll. The control system gain factors (a_o, a_1, and b_o') for the pitch, yaw and roll axes are shown in Figure 6, along with the engine and control actuator locations. Sloshing of the propellants in the S-I stage is reduced by the anti-slosh baffles to the level where it does not significantly affect the control system. First and second bending mode influences on the control system are suppressed by phase shaping and/or attenuation of those frequencies ($\approx$2 to $\approx$4 cps) and ($\approx$6 to $\approx$12 cps) in the Flight Control Computer. (See Figure 11).

Pitch programming of the vehicle is provided by a cam device (located in the Servo Loop Amplifier Box) which contains the pre-selected tilt program.

The primary 28 v. d. c. power for the vehicle system is supplied by two 2650 amp-min. capacity batteries. These batteries also supply power to the 1800 VA Rotary Inverter which provides 400 cycle, 115 v. a. c. power for the vehicle systems.

The following devices are being test flown on SA-2 to obtain some of the necessary engineering information required for the development of the guidance and control system of future SATURN C-1 vehicles:

a. Three ST-90 mounted AMAB-4 Accelerometers which provide 3 axes velocity information in digital form.

[redacted]

b. A Guidance Signal Processor - Repeater which processes the digital velocity signals and conditions them for telemetering.

c. A 3 axes Control Rate Gyro Package which provides attitude rate information as a. c. signals.

d. A Control Signal Processor which converts the attitude rate information to d. c. control signals and conditions them for telemetering.

e. Pitch and yaw Control Accelerometers which measure lateral vehicle accelerations, converts the signals to d. c. control signals and conditions them for telemetering.

f. A Q-ball Transducer which measures pitch and yaw angles-of-attack and dynamic pressure, converts the signals to d. c. and conditions them for telemetering.

3. Trajectory

The basic flight trajectory for SA-2 (with all eight engines operating) is outlined in Figure 4. The tilt program is based on the seven engines operating case. The vehicle pitch angle-of-attack brought about by this compromise is rather small and therefore acceptable from the control standpoint. Cutoff of the inboard engines is initiated by the propellant level sensors around 111 seconds after liftoff. The outboard engines are cut off six seconds later by a signal from the Program Device.

4. Telemetry System

The telemetry system of eight separate RF links, has 30 components. Figure 9 shows the type of telemetry unit, its transmitter frequency, and measuring capacity. FM/FM is used extensively on SA-2. Two SS/FM units which are used to transmit high frequency information (vibration and accoustical measurements) have been added to SA-2.

5. Measuring System

The measuring system has more than 800 measuring components (signal conditioners a. c. and d. c. amplifiers, zone boxes, etc., and measuring transducers, flowmeters, accelerometers, pressure gauges, etc.), which provide over 600 individual measurements (≈530 flight and ≈95 blockhouse).

6. R. F. Systems (Range Safety and Tracking)

The five R. F. systems used for range safety and tracking are shown in Figure 10. These systems are comprised of 26 components.

a. Command System: The function of the command system is to receive a R. F. command signal from the ground transmitter (range safety officer) to energize the vehicle's fuel dispersion system (vehicle command destruct). Range safety requires that each vehicle launched from the Atlantic Missile Range carry a command destruct system. The system is comprised of two separate and independent units; the only items that are common are the antennas and some cabling. Each unit receives its power from a separate 28 v. d. c. battery.

On the SA-2 flight, release of the water ballast in the S-IV and S-V dummy stages will be made (Project Highwater - See Figure 4). The release will be by command from the range safety officer through the vehicle command destruct system, about 45 seconds after cutoff. This experiment will also be a positive test of the S-I stage command destruct system.

b. Azusa and C-Band Radar Systems: These systems provide signals to a ground computer complex to obtain position and velocity information. These trajectory data are presented on plotting boards for the range safety officer to use in determining "real time" vehicle performance. In addition, they are also used for the post flight evaluation of the vehicle's trajectory.

c. S-Band Radar and UDOP Systems: These systems provide trajectory data (vehicle position and velocity) for the post flight evaluation of the vehicle's performance.

E. F. Noël
for F. W. BRANDNER

Enc: (11)
Sketches

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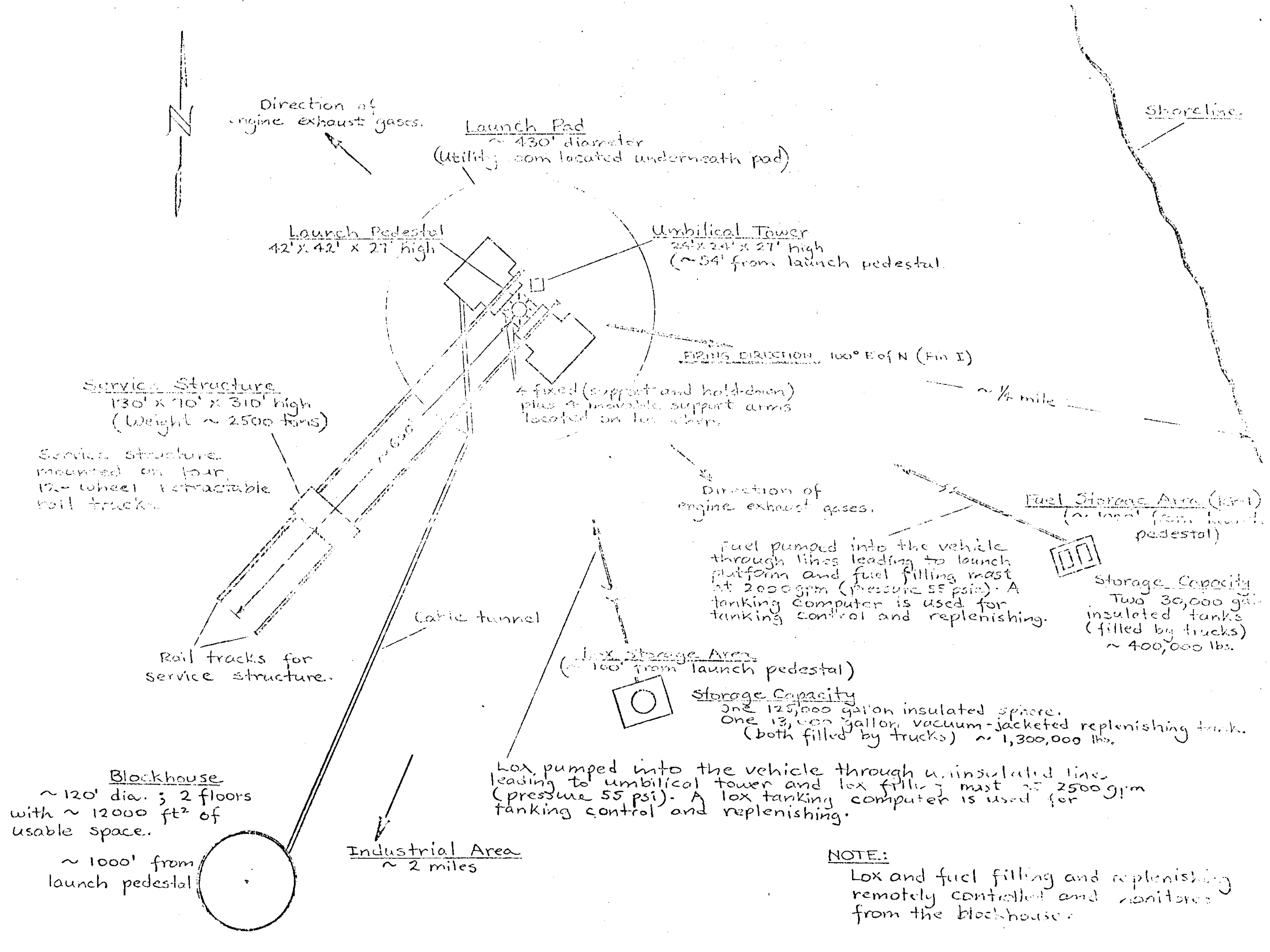


Figure 1

VLF 34

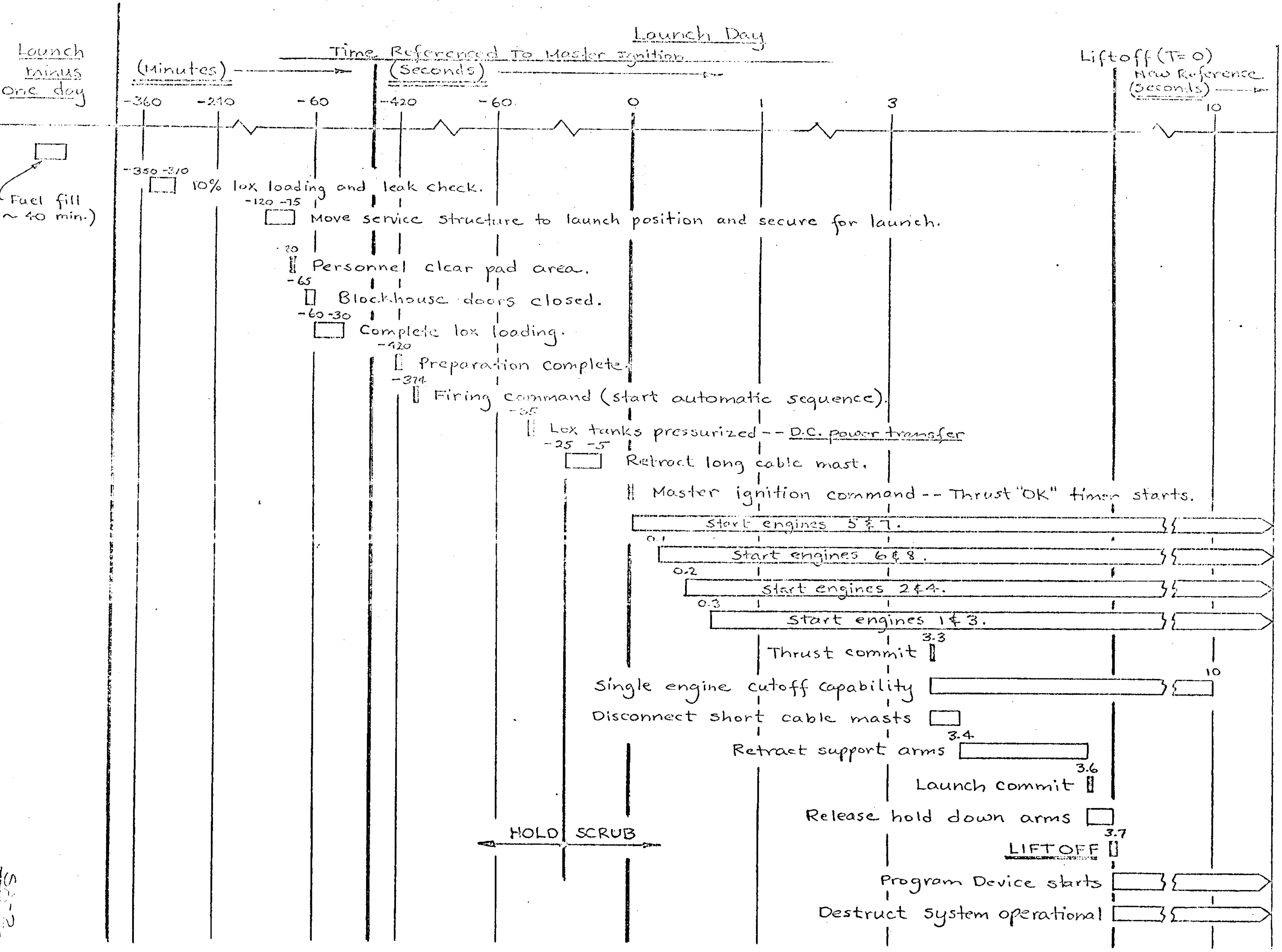
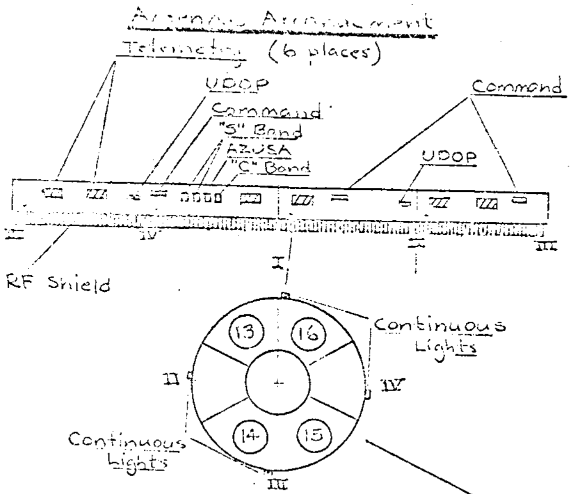


Figure 2

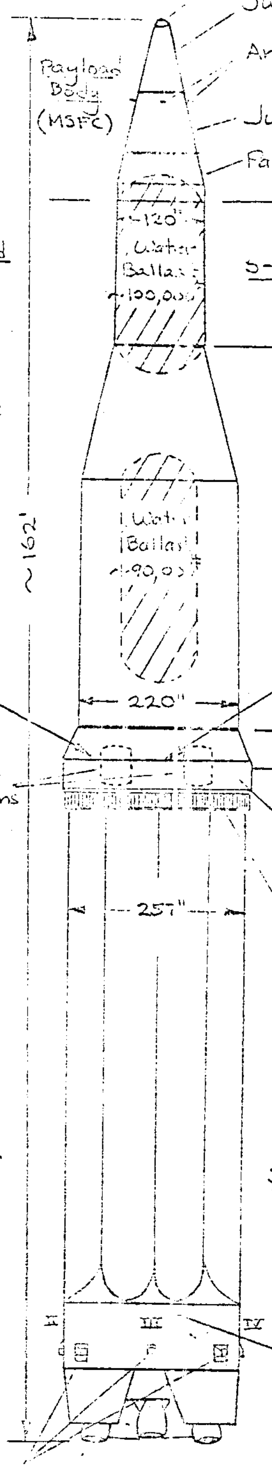
SA-2
Launch Countdown

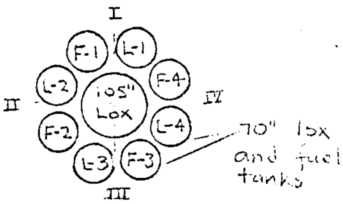
Vehicle liftoff weight
~ 910,000 lbs.

Propellant weight at
liftoff ~ 620,000 lbs.
(Lox + RP-1)



Canister Arrangement
(View looking down)





Lox And Fuel Tank Arrangement
(View looking down)

Major Electrical Components Located in Canisters

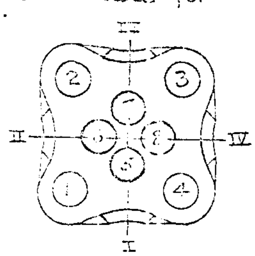
Canister 16
- All telemeter equipment. (8 telemeter assemblies)

Canister 13
- Master measuring voltage supply.
- Measuring distributor.
- Signal Conditioning equipment for all meas. in forward vehicle area.
- Time base simulator (passenger).
- Meas. rate gyros (P, Y, R) ±100°/sec.

Canister 15
- ST-90 & Servo loop amplifier box.
- Control computer.
- Program device J.
- Control rate gyros (passenger) P, Y, R; ± 10°/sec.
- Guidance signal processor (passenger).
- Control voltage supply.
- Flight sequencer & slave.
- Control distributor.
- Command receivers (2).

Canister 14
- Batteries (2) 28 vdc.
- Inverter (1800 VA).
- Power distributor.
- UDOP.
- Azusa.
- C-Band Radar.
- S-Band Radar.

NOTE: Canisters have pre-flight cooling ONLY!



View looking forward

Engine Data

- Start System: Solid propellant turbine spinner plus hypergolic fuel mixture.
- Four inboard engines; fixed mounted: 3° cant angle.
- Four outboard engines; gimble mounted - provides ± 7° gimbaling: 6° cant angle.
- ~ 165,000 lbs. thrust each engine.

Figure 3

SA-1
Vehicle Configuration

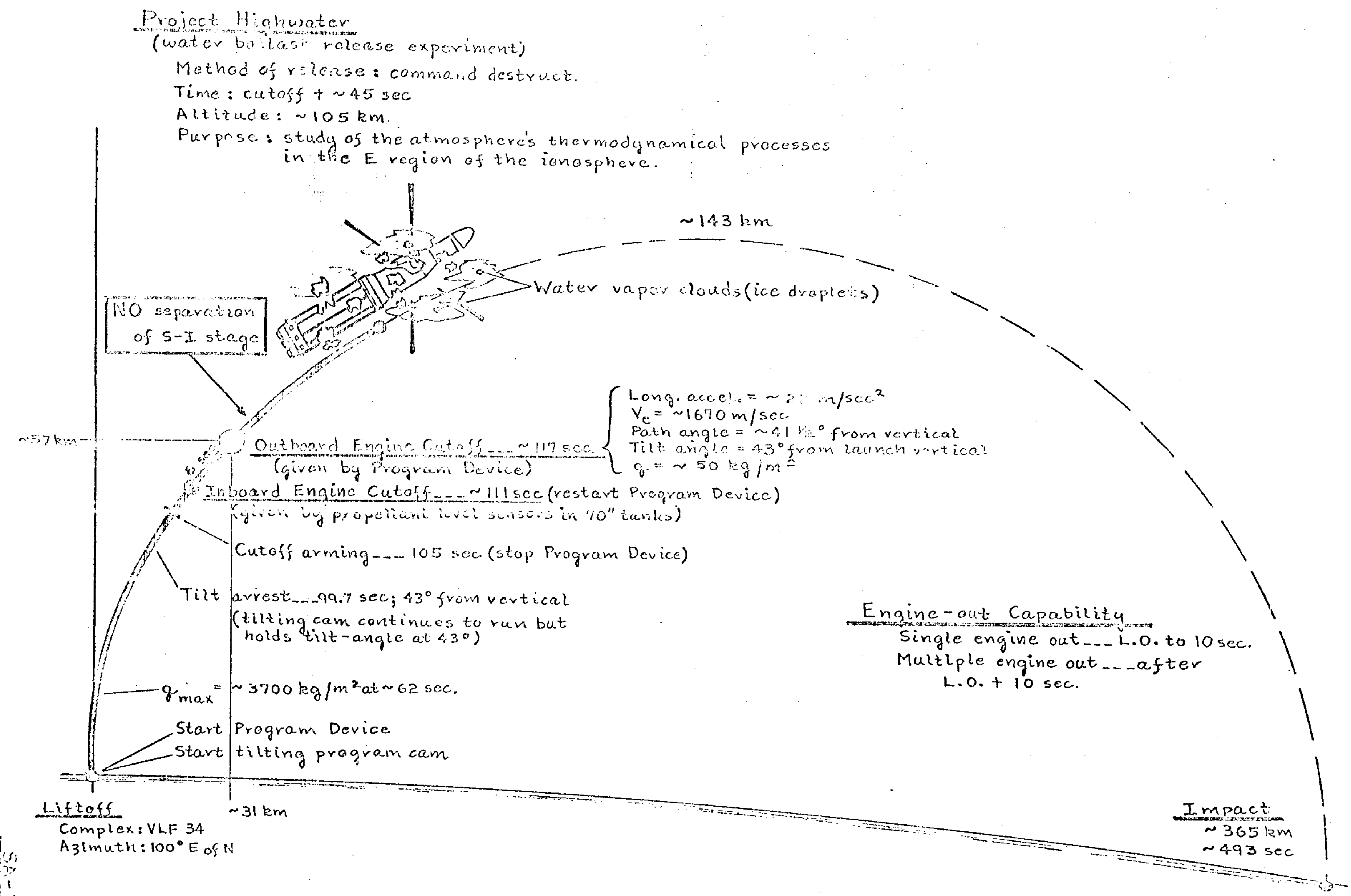


Figure 4

SA-2
Trajectory Information

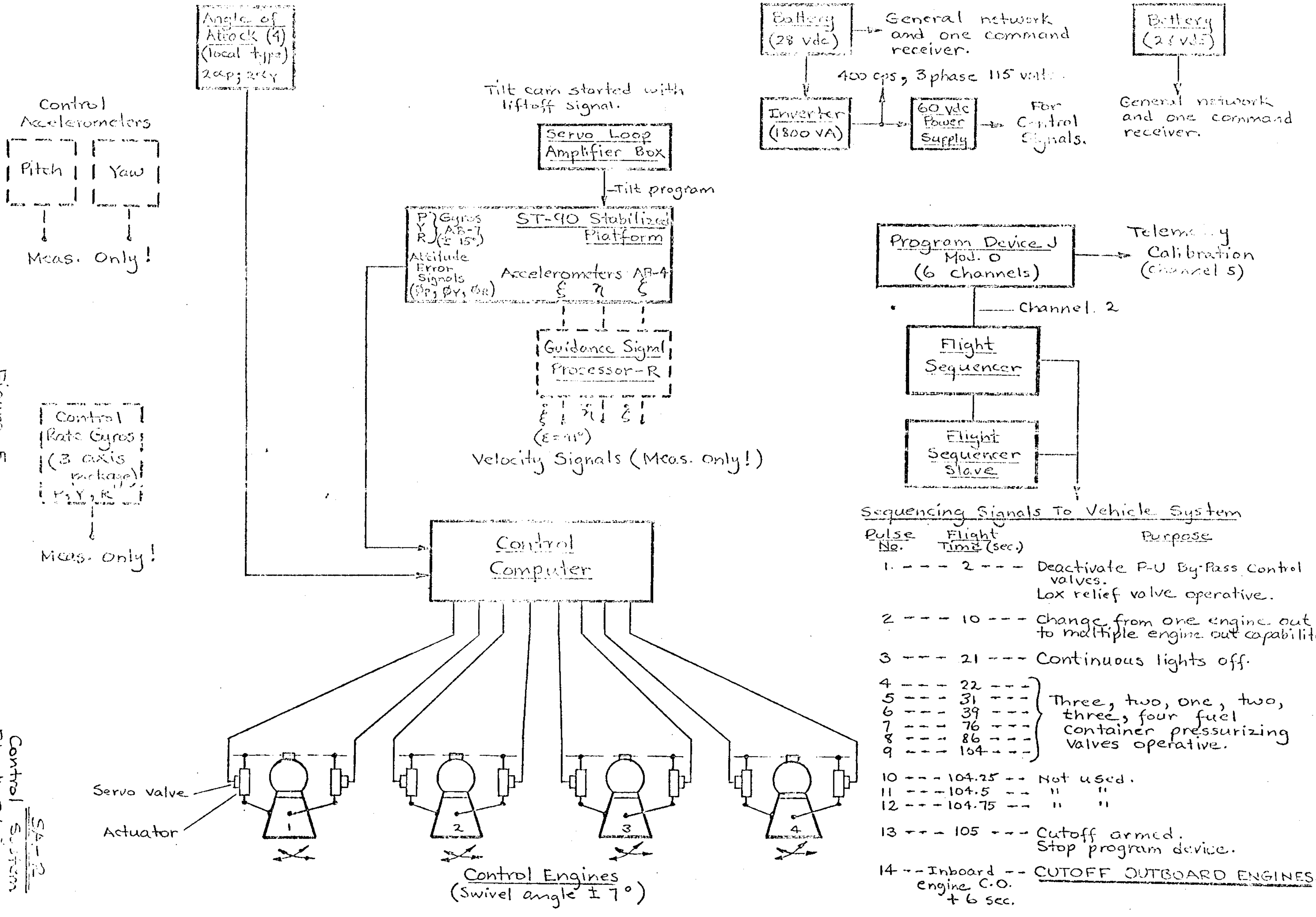


Figure 5

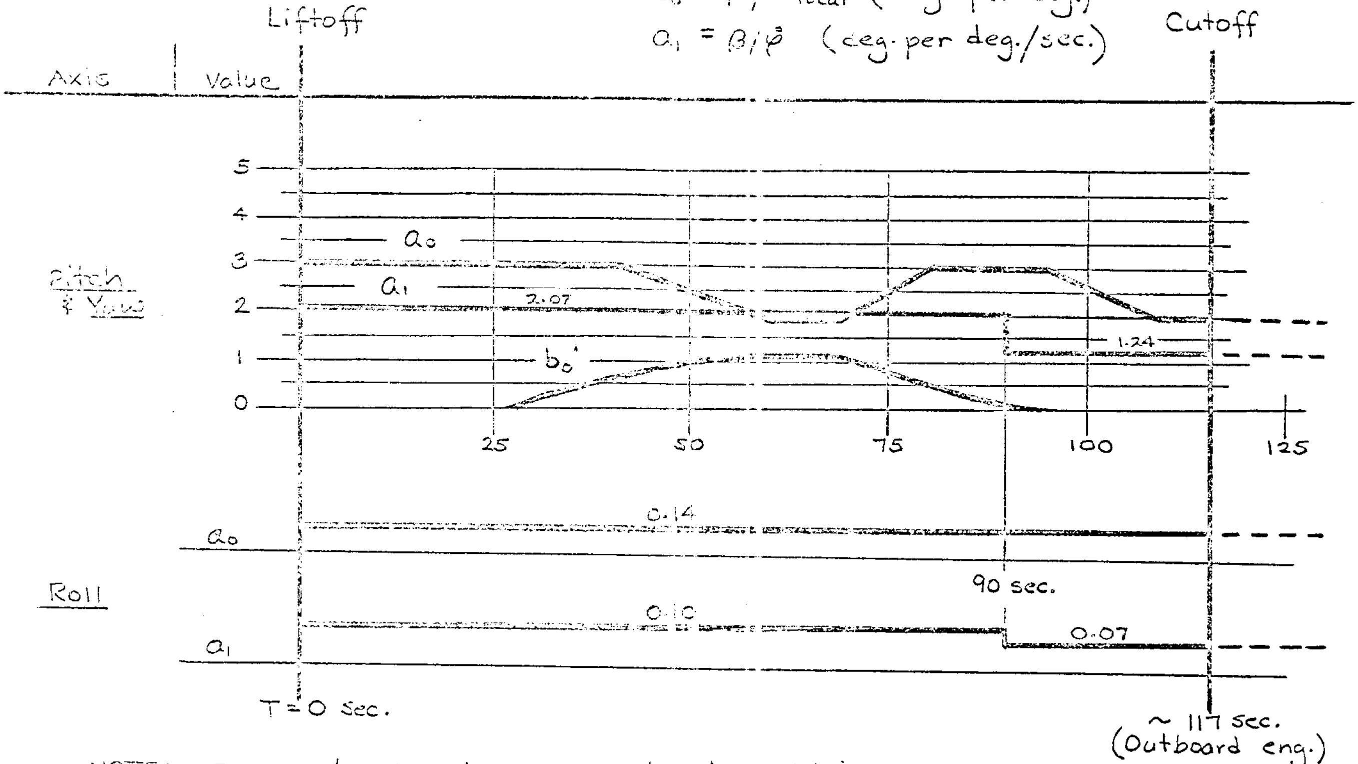
SA-2
Control System Block Diagram

Control System Gain Factors

$a_0 = \beta/\varphi$ (deg. per deg.)

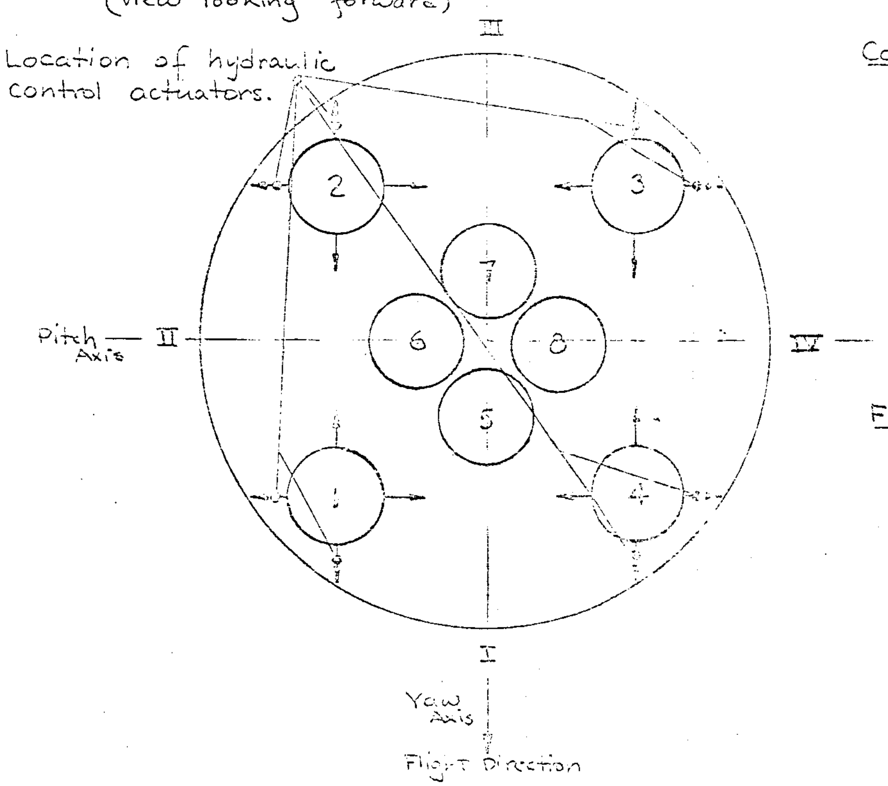
$b_0' = \beta/\alpha_{local}$ (deg. per deg.)

$a_1 = \beta/\dot{\varphi}$ (deg. per deg./sec.)



NOTE: For exact gain values see Astrionics Division Memo. NAV 562/61 dated Sept. 18, 1961

Engine and Actuator Arrangement
(View looking forward)



Control Engines (1, 2, 3, 4)
Swivel angle ±7°
Mounting radius 95"
Cant angle 6°

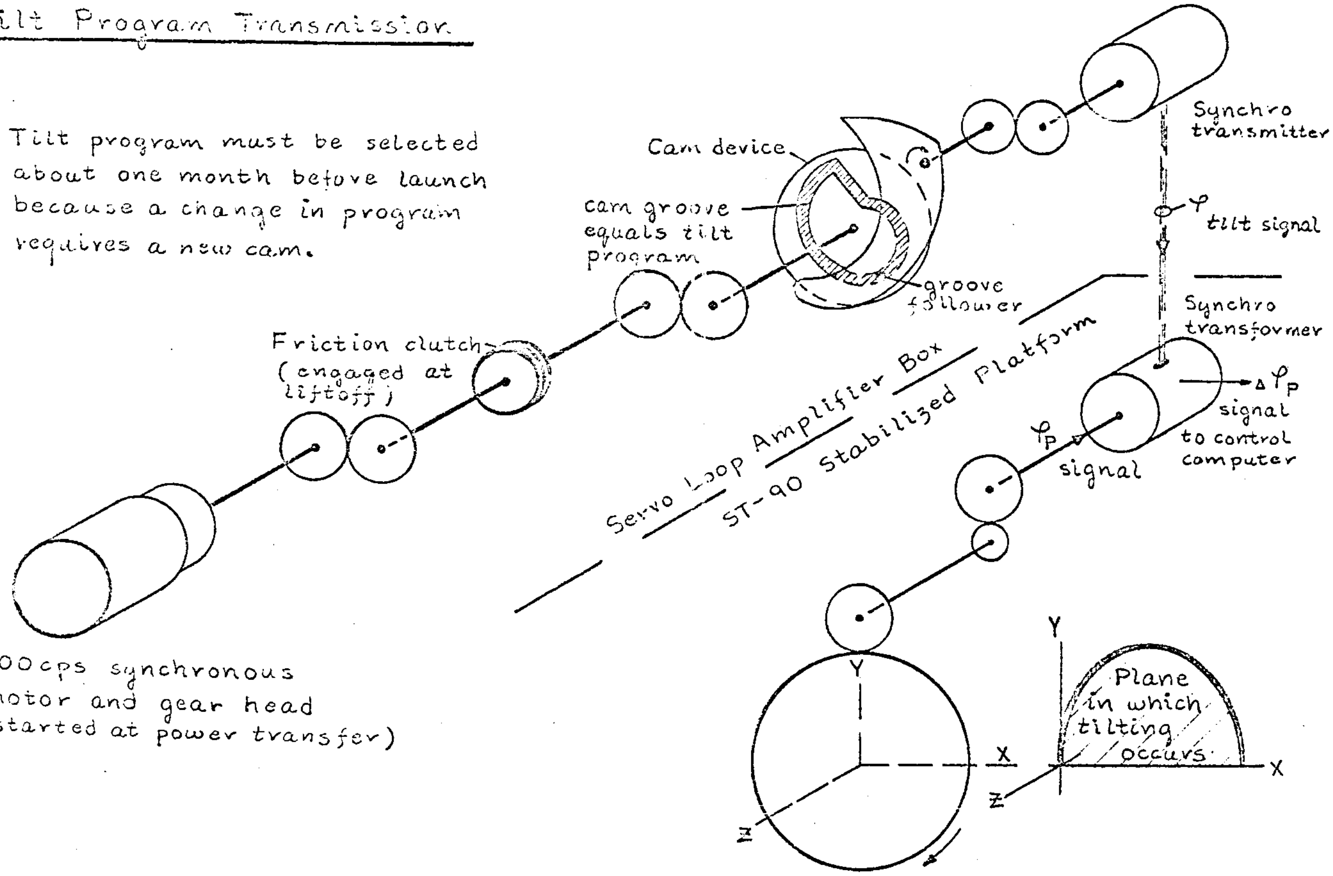
Fixed Engines (5, 6, 7, 8)
Mounting radius 32"
Cant angle 3°

Figure 6

SA-2
Control Information

Tilt Program Transmission

Tilt program must be selected about one month before launch because a change in program requires a new cam.



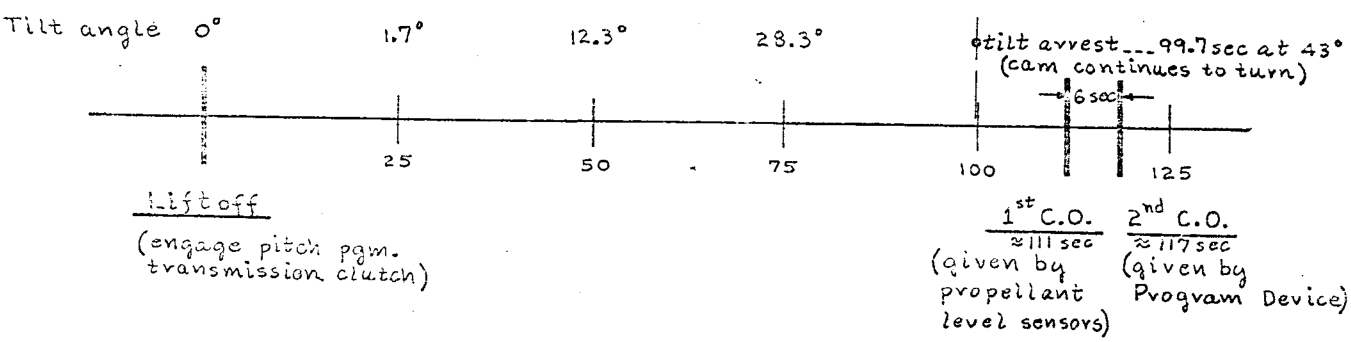
Tilt Program Information

Maximum tilt rate: 0.7°/sec

Final tilt angle: 43° from launch vertical

Tilt arrest: 99.7 sec after liftoff

Tilt program is based upon the engine-out concept; that is, the tilt angle is proper for only 7 engines operating from liftoff.



SA-2

Tilt Program Information

Figure 7

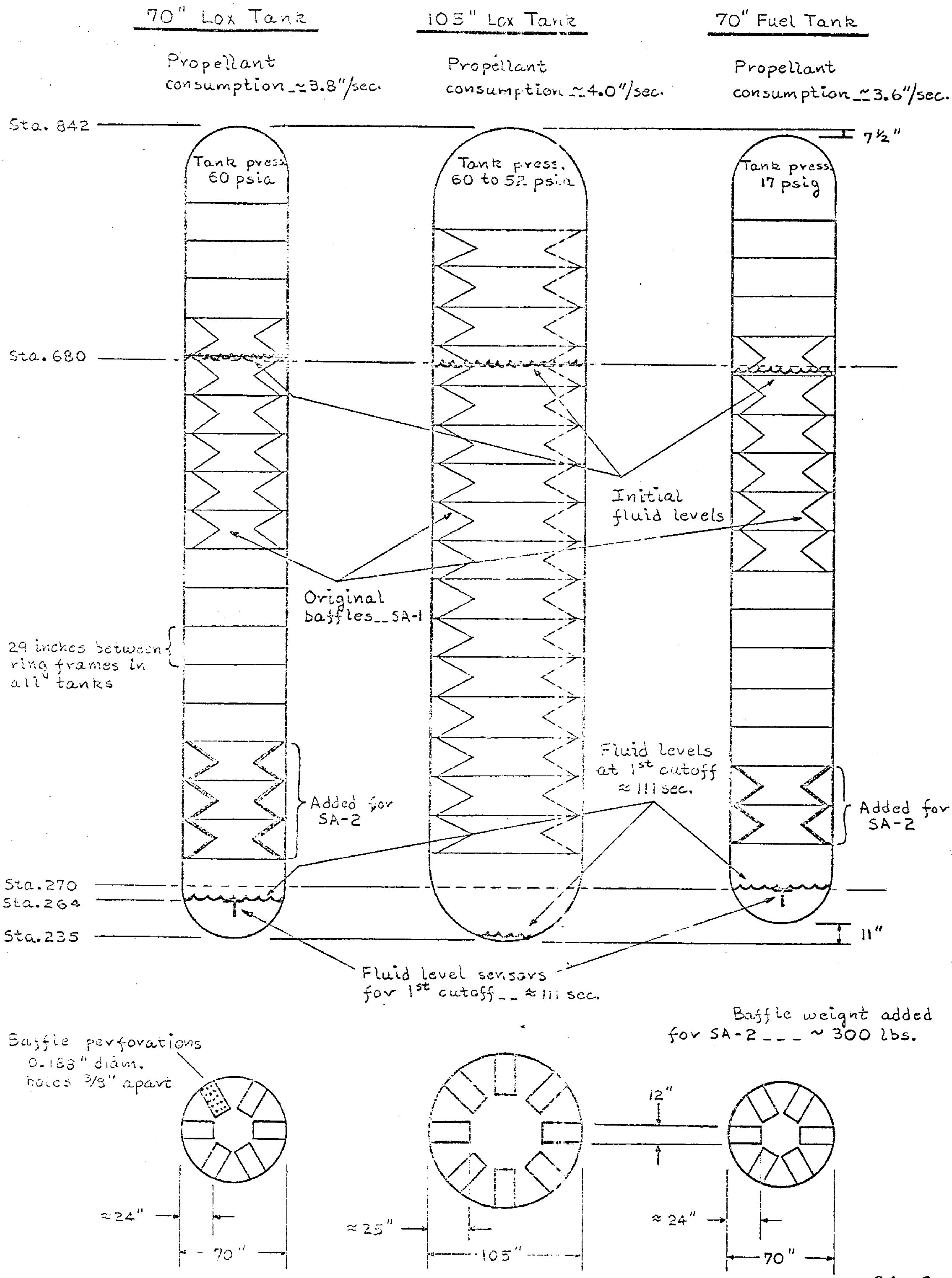


Figure 8

SA-2
Propellant Tanks

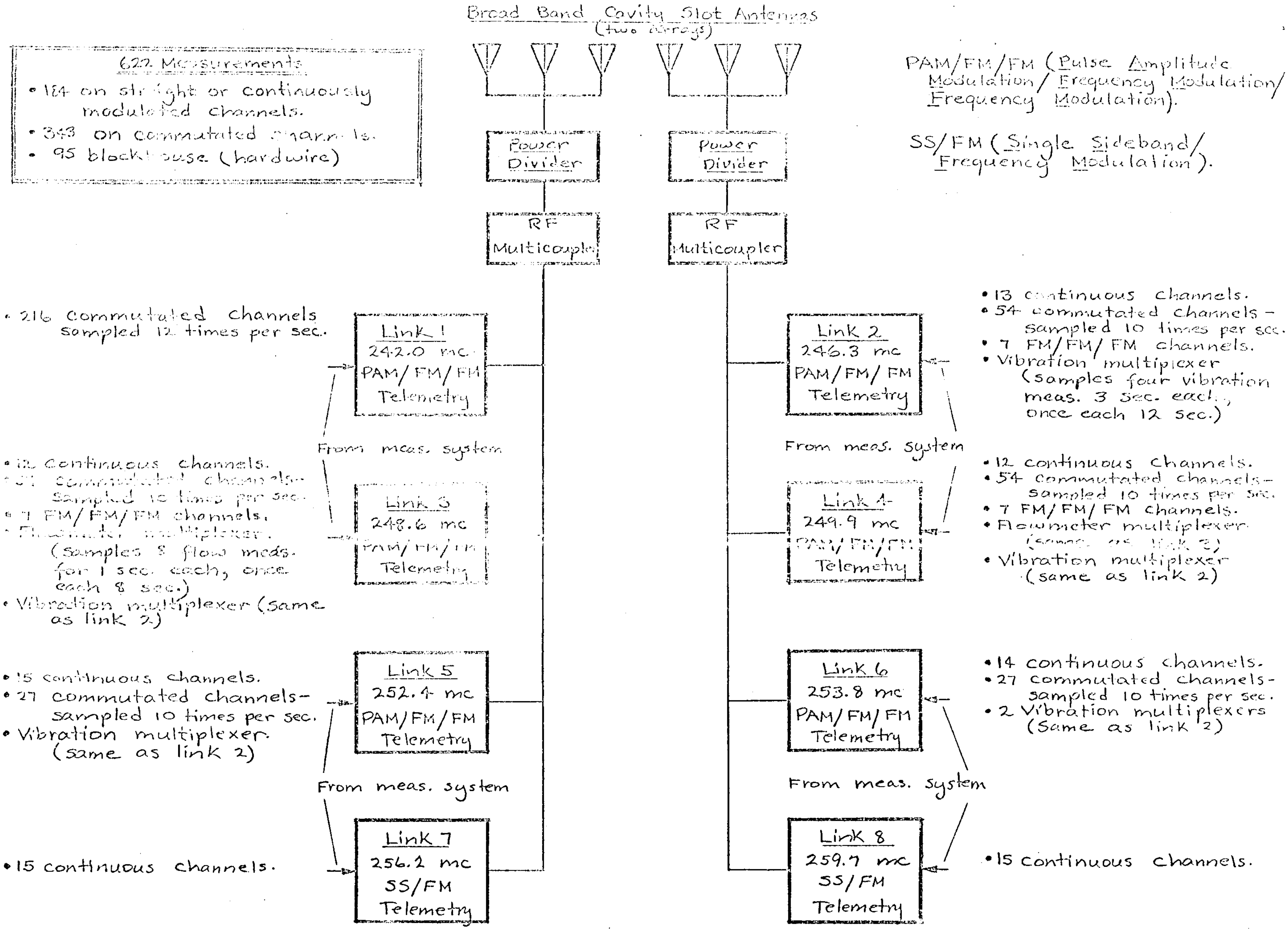


Figure 9

SA-?
Telemetry System

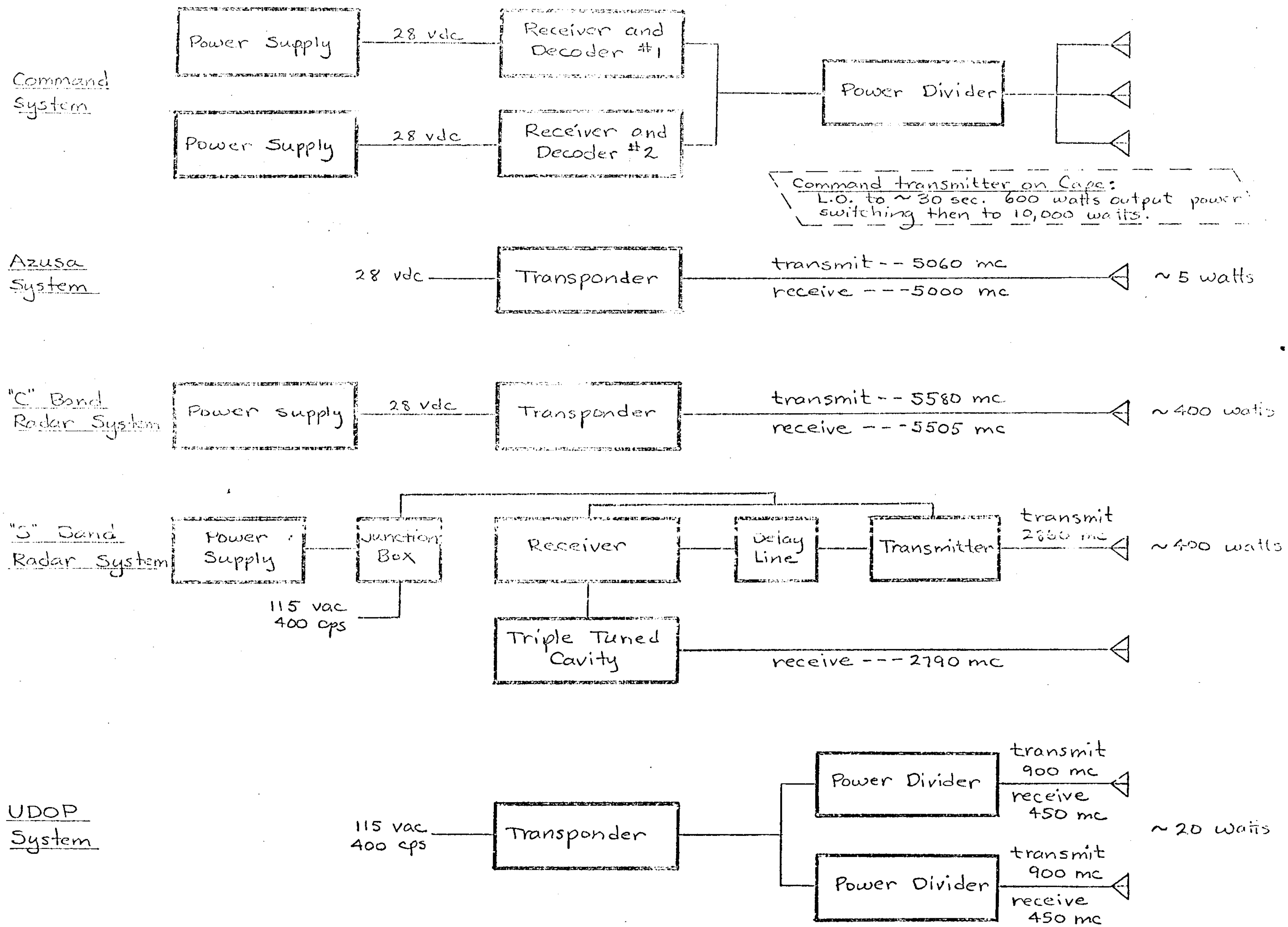
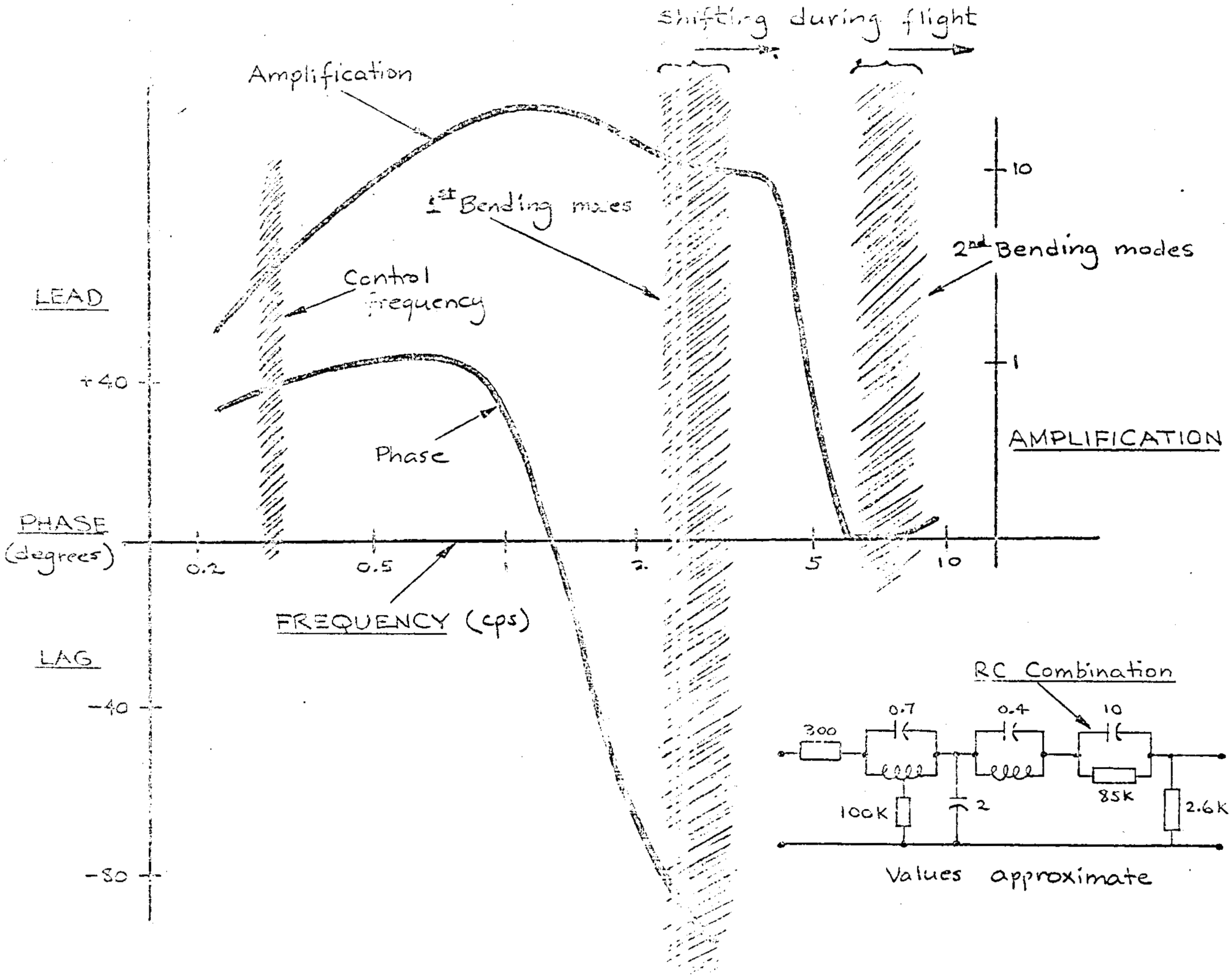


Figure 10

SA-2
RF Systems



The shaping network operates in the following ways:

1. For the control frequency (~0.3 cps) it acts as a RC combination where a 40° phase lead with respect to the output signal (φ) is achieved.

2. For the 1st bending frequency (2-4 cps) it acts as a shaping network which provides approximately 60-80° phase lag. An amplification goes with it but has no significant importance.

3. For the 2nd bending frequency (6-12 cps) it acts as an attenuator.

Frequencies above 10 cps are suppressed by the servo loop.

SA-2

Simplified Explanation of Shaping Network - $\varphi_{P,Y}$

Figure 1